

# Relationship Between Daytime Sleepiness and Blood Pressure in Healthy Older Adults

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**Background:** Some sleep disorders have been linked to hypertension, but few studies have examined the relationship between daytime sleepiness and blood pressure (BP). This study attempted to determine whether scores on a short questionnaire assessing daytime sleepiness (Epworth Sleepiness Scale [ESS]) were associated with BP and could be used to predict hypertension after 5 years in healthy older adults who had not previously been diagnosed with hypertension.

**Methods:** A group of 157 healthy men and women 55 to 80 years of age completed an extensive medical examination, a series of psychosocial tests, and two 24-h ambulatory BP sessions. After 5 years the procedures were repeated in 133 (85%) of the subjects. Psychosocial variables and BP were compared in subjects scoring high (score of  $\geq 10$ ) and low ( $< 10$ ) on the ESS.

**Results:** Compared to individuals with low ESS scores, those scoring high had increased casual and sleep BP as

well as higher systolic BP levels and diastolic BP variability during waking hours, and reported higher levels of anger, depression, anxiety, and intensity of psychological symptoms as well as lower defensiveness. Individuals with high ESS scores were more likely to be diagnosed with hypertension 5 years later. Groups with high and low ESS scores did not differ significantly on any other variables.

**Conclusions:** The ESS, a simple measure of daytime sleepiness, identified individuals at risk for hypertension. Future studies should investigate the possibility that diagnosis and treatment of daytime sleepiness could aid in BP reduction and ultimately in decreased morbidity and mortality from cardiovascular disorders. *Am J Hypertens* 2004;17:787-792 © 2004 American Journal of Hypertension, Ltd.

**Key Words:** Ambulatory blood pressure, excessive daytime sleepiness, hypertension.

Daytime sleepiness is a common but frequently misunderstood complaint among older individuals. Approximately 20% of subjects ( $\geq 65$  years of age) in the Cardiovascular Health Study reported being sleepy during daytime hours.<sup>1</sup> Although frequently viewed as a benign occurrence, excessive daytime sleepiness (EDS) has been associated with increased risk of cardiovascular death.<sup>2,3</sup> Moreover, although prevalent among older populations, EDS may be less relevant to age and more a function of health conditions in the elderly.<sup>4</sup> The major aim of this study is to evaluate the role of EDS in hypertension.

Although hypertension and elevations in BP have been linked to sleep disorders such as obstructive sleep apnea,<sup>5</sup> little is known about the relationship between hypertension and daytime sleepiness. In patients  $> 18$  years of age, there was a positive relationship between the Epworth Sleepiness Scale (ESS) scores and hypertension severity;

but after correcting for age, the results were not significant.<sup>6</sup> However, high ESS scores were found in elderly women who reported having hypertension.<sup>1</sup> The ESS has been correlated with depression and intensity of psychological symptoms, leading to the implication that the ESS scores might be influenced by emotional and psychosocial factors.<sup>7</sup> Using the ESS, we related EDS to daytime and night-time BP in healthy older adults who had never been diagnosed or treated for either hypertension or any sleep disorder. We predicted that, compared with individuals who showed few signs of daytime sleepiness, those who were sleepy during the day would have higher BP and would be more likely to develop hypertension after 5 years. Finally, to determine whether the ESS was associated with psychosocial factors, we looked at the relationship between daytime sleepiness and anger, hostility, depression, defensiveness, anxiety, and psychological symptoms in this healthy, older population.

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**Table 1.** Characteristics of subjects during initial study phase

Characteristic	Mean $\pm$ SD
Age (y)	66.4 $\pm$ 5.8
Body mass index (kg/m <sup>2</sup> )	24.7 $\pm$ 2.8
Education (y)	15.4 $\pm$ 2.7
Exercise (h/week)	10.0 $\pm$ 8.0
Alcohol (drinks/week)	2.8 $\pm$ 4.1
Coffee (cups/day)	1.8 $\pm$ 1.9
Glucose (mg/dL)*	114.6 $\pm$ 28.9
Total cholesterol (mg/dL)	227.6 $\pm$ 34.4
LDL cholesterol (mg/dL)	135.9 $\pm$ 32.8
HDL cholesterol (mg/dL)	62.4 $\pm$ 20.1
Triglycerides (mg/dL)	143.2 $\pm$ 78.5

\* After 2 h of 75-g glucose load.

## Methods

### Subjects

Subjects were recruited by media advertisements and from senior centers in Los Angeles. Data were initially obtained on a healthy group of 65 men and 92 women aged 55 to 80 years. Ethnic composition was as follows: 117 individuals of white ethnicity, and 25 Asian, 12 African American, two Latino, and one Native American (for group characteristics, see Table 1). Individuals were excluded if they reported a serious existing or prior illness, or any current or past use of medications influencing either the cardiovascular or cerebrovascular system. In addition, no subjects had a history that included drug or alcohol abuse or a head injury resulting in loss of consciousness of >10 min. Any subject with obesity as defined by a body mass index (BMI) >30 kg/m<sup>2</sup> was excluded. The Brief Symptom Inventory<sup>8</sup> and the short form of the Geriatric Depression Scale<sup>9</sup> (score <5) excluded individuals with psychiatric disorders. The Mini Mental State Exam (MMSE) excluded those with cognitive problems<sup>10</sup> (score <26). Self-reports were confirmed by medical examination (see Procedures) and prior medical records. Abnormal findings provided further basis for exclusion (for more details on exclusionary factors, see Ref.11). Although it was not an exclusionary factor, there were no indications of obstructive sleep apnea from medical histories or physician examinations.

Five years later, 133 subjects (85%) returned for the follow-up phase. Comparisons between the original group of subjects who completed the follow-up and those who did not revealed no significant differences ( $\chi^2$  or *t* test) at baseline for any of the variables.

### Procedures

The same procedures were used initially and during follow-up and included three sessions. During the first session subjects gave informed consent (approved by the Institutional Review Board of the University of California at Los Angeles), followed by the medical examination. A

few days later subjects returned for two 24-h ambulatory BP monitoring sessions on weekdays, about 1 week apart. All sessions began in early morning hours.

### Session 1

**Medical Examination** During Session 1, physical and medical status examinations were completed by the physician. The session included a complete health history, 12-lead electrocardiography, urinalysis, and chemical panel.<sup>11</sup> Medical records were obtained from subjects' physicians.

**Test Inventories** After completing the physical examination, subjects filled out the following test inventories. 1) The ESS assesses the general level of daytime sleepiness by having individuals rate the likelihood of dozing during eight different daytime situations. Scores >10 are considered to be EDS. The ESS is reliable, internally consistent, and has been validated against objective measures taken during polysomnography.<sup>12</sup> 2) A short form of the Geriatric Depression Scale measures depression.<sup>9</sup> 3) The Brief Symptom Inventory provides an index of current psychological symptom intensity by measuring symptoms on nine different psychiatric dimensions.<sup>8</sup> 4) The Cook-Medley Hostility subscale of the MMPI reflects a cynical and mistrusting attitude toward others.<sup>13</sup> 5) The Spielberger Anger Expression Scale provides scores on two dimensions of anger expression: anger out (directing anger outward) and anger in (suppressing anger).<sup>14</sup> 6) The Marlowe-Crowne Social Desirability Scale<sup>15</sup> measures defensiveness, the tendency to deny or suppress negative emotions.<sup>16</sup> 7) The Spielberger Trait Anxiety Inventory measures the general disposition to experience anxiety frequently.<sup>17</sup> 8) The MMSE assesses cognitive mental status.<sup>10</sup>

### Sessions 2 and 3

**Ambulatory BP Monitoring** At Session 2, three standard casual BP readings<sup>18</sup> were recorded after 5 min of sitting. This was followed by attachment of the 24-h BP ambulatory monitoring equipment. Subjects returned the following day for monitor removal. Casual and ambulatory BP measurements were repeated during session 3, which was conducted 1 week later. In the morning after each night of ambulatory BP recording, subjects filled out a questionnaire providing subjective information on their sleep that night (quality of sleep, number of times out of bed at night, total time out of bed at night, total time in bed, and number of minutes to fall asleep).

Ambulatory BP was recorded by the Accutacker II (Suntech Medical Instruments, Raleigh, NC), which has been widely used in clinical and research studies with established reliability and validity.<sup>19</sup> The BP was recorded on a variable schedule for a 24-h period, three times per hour during waking and once per hour during sleep (based on subjects' estimates of time of going to sleep and awakening). The differentiation of waking from sleep was con-

firmed by an activity monitor (Mini-Motionlogger, Ambulatory Monitoring Inc., Ardsley, NY), which was also used to account for effects of activity on BP.<sup>20</sup>

Ambulatory data were edited for artifacts based on Accutracker reading codes. Editing was done by set rules.<sup>21</sup> Classification of each reading as waking or sleep was based on diary entries and postsession reports. Only night-time sleep values were included in the sleep category and daytime nonsleep values in the waking category.

Means were obtained for each session for casual BP and for the following ambulatory BP measures: waking level, sleep level, waking variability, and sleep variability. For a given individual, variability was based on the SD of the waking and of the sleep period for a given day. The coefficient of variation was also used but did not alter the results. Only findings with the SD were included. All analyses were based on means of BP values over the 2 days.

**Oximetry** The Nonin 8600 series pulse oximeter (Nonin Medical, Plymouth, MN) was not initially used but was added during the follow-up to measure blood oxygen saturation levels during the night and to detect the presence of sleep apnea. A transducer was fitted on the subjects' fingernail and sampled oxygen saturation levels every 2 sec during night-time ambulatory BP recording. A computer program (Profox, Escondido, CA) provided the following variables: number of desaturation events >4% and lasting <3 min, lowest oxygen saturation, mean oxygen saturation, mean low oxygen saturation, mean low desaturation, and percentage of time that saturation events were  $\geq 90\%$ . Data were edited for both start and stop times that corresponded to reported bedtime (or sleep onset) and reported wake-up time in the morning to determine oxygen desaturation index, which was calculated as the number of desaturations per hour of sleep.

**Statistical Analysis** Although ESS scores >10 are usually associated with sleep disorders,<sup>12</sup> our distribution, like that of 620 drivers (16 to 86 years of age) in the study by Benbadis et al<sup>22</sup> was normally distributed and showed a drop after a score of 9. Consequently, we divided the subjects into two groups: subjects with high ESS (scores of  $\geq 10$ ;  $n = 34$ ), and those with low ESS (scores <10;  $n = 123$ ). Analysis of covariance (ANCOVA) in a group  $\times$  gender model was done with the following dependent systolic blood pressure (SBP) and diastolic blood pressure (DBP) values: ambulatory waking and sleep level, ambulatory waking and sleep variability, and casual BP. Age and BMI were used as covariates; gender and ESS groups were independent variables. Tests were done on data obtained during the initial phase of the study and also during follow-up. Activity had no appreciable effect and was not included in the analyses. In addition, psychosocial factors were used as dependent variables in group  $\times$  gender ANCOVA, with age as a covariate.

## Results

### Prospective Findings

The mean score on the ESS was  $7.15 \pm 3.61$  during the initial phase and  $6.98 \pm 3.75$  during follow-up, showing no significant difference after 5 years. The correlation of the test with itself over time was 0.76 ( $P < .0001$ ). Of the subjects who participated in both study phases, during the follow-up 12 individuals (9%) were diagnosed with hypertension by their private physicians and treated with antihypertensive medication. These subjects had higher initial scores on the ESS ( $9.8 \pm 4.91$ ) than did the nonhypertensive subjects ( $6.83 \pm 3.28$ ) ( $t$  test,  $P = .005$ ). Hypertensive individuals also had higher initial casual BP ( $137.0 \pm 10.5/78.8 \pm 6.8$  mm Hg) than did nonhypertensive subjects ( $117.6 \pm 13.2/71.4 \pm 8.9$  mm Hg) (SBP,  $P = .0001$ ; DBP  $P = .007$ ). Groups did not differ by age or BMI. Oximeter values showed no significant differences between individuals with and without a diagnosis of hypertension. When hypertensive subjects at follow-up included not only those diagnosed by their physicians for hypertension but also individuals with a casual SBP  $\geq 140$  mm Hg or DBP  $\geq 90$  mm Hg,<sup>18</sup> results were similar. Hypertensive subjects again scored higher on the initial ESS ( $8.41 \pm 3.74$ ,  $n = 34$ ) than did nonhypertensive subjects ( $6.64 \pm 3.37$ ,  $n = 99$ ) ( $t$  test,  $P = .012$ ).

### Cross-Sectional Findings

Analyses using  $t$  tests or  $\chi^2$  indicated that during the initial study phase, individuals scoring high on the ESS did not differ from those with low scores with regard to demographic measures (age, BMI, gender, education, hours of exercise, alcohol, caffeine intake), 2-h glucose (after 75-g load), lipids, MMSE scores, activity level and variability (waking, sleep, and 24-h), or scores on the sleep quality questionnaire. In addition, there was no relationship between number of diary indications of napping during the day and ESS scores. Similar findings existed during the follow-up phase. Oximeter measures obtained during follow-up were unrelated to the ESS.

The ANCOVA results showed that during the initial phase, compared with the low ESS group, high ESS subjects had consistently higher casual and ambulatory BP values. The high ESS group had significant elevations in casual and sleep SBP and DBP, waking SBP, and DBP waking variability (Table 2).

Compared to women, men had higher casual SBP and DBP and higher DBP during sleep but lower SBP and DBP waking variability. There were two significant ESS  $\times$  gender interactions. Men with high ESS scores had higher casual DBP than men and women scoring low and women scoring high on the ESS ( $P < .05$ ). Also, women scoring high on the ESS had higher SBP waking variability than men with either high or low ESS scores ( $P < .05$ ) (Fig. 1). Although a larger percentage of men (27%) than women (17%) were in the high ESS group, this was not a significant difference.

**Table 2.** Blood pressure (BP) values during initial study phase

BP Variable	Men (n = 65)	Women (n = 92)	High ESS (n = 34)	Low ESS (n = 123)
SBP, casual	125.4 ± 13.4*	119.1 ± 13.9	126.0 ± 15.7†	118.5 ± 12.8
DBP, casual	76.4 ± 8.9‡	70.4 ± 7.9	75.0 ± 9.6*	71.7 ± 8.1
SBP, wake	130.0 ± 11.7	127.0 ± 11.4	131.2 ± 13.3*	125.8 ± 10.9
DBP, wake	76.1 ± 6.5	73.8 ± 6.6	75.9 ± 7.1	73.9 ± 6.3
SBP, sleep	114.5 ± 12.2	110.7 ± 13.3	116.5 ± 15.3‡	108.7 ± 12.2
DBP, sleep	65.7 ± 7.2†	61.7 ± 7.0	65.5 ± 7.8†	61.9 ± 6.9
SBP, wake variability	13.3 ± 2.7†	15.1 ± 3.2	14.5 ± 3.7	13.8 ± 2.8
DBP, wake variability	9.9 ± 2.3‡	12.4 ± 3.2	11.7 ± 3.7*	10.5 ± 2.8
SBP, sleep variability	9.6 ± 3.1	9.9 ± 3.2	10.1 ± 3.4	9.5 ± 3.1
DBP, sleep variability	7.9 ± 2.8	7.8 ± 2.7	8.0 ± 3.6	7.6 ± 2.5

DBP = diastolic BP; ESS = Epworth Sleepiness Scale; SBP = systolic BP.

Values represent BP mean ± SD (in mm Hg). Values are derived from ANCOVA with Epworth Sleepiness Scale (ESS) and gender as factors and age and body mass index as covariates. Significance values are for men versus women and high versus low ESS groups. The interactions of ESS and gender are shown in Fig. 1.

\*  $P < .05$ ; †  $P < .01$ ; ‡  $P < .001$ .

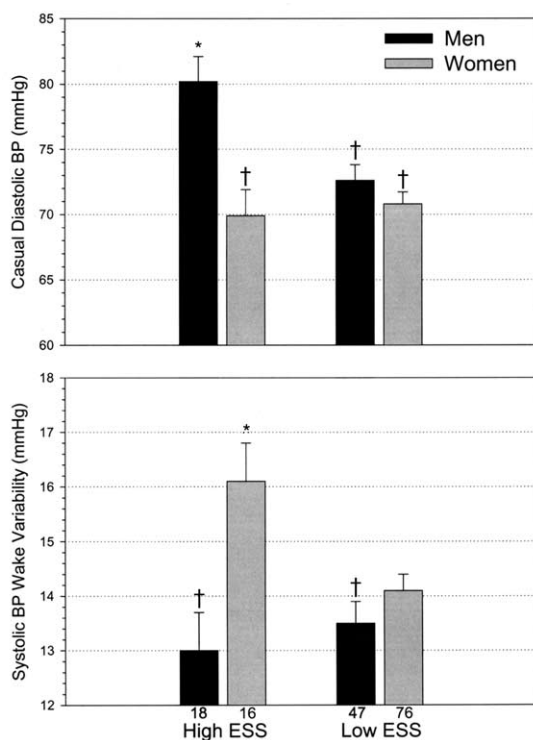
In ANCOVA with psychosocial scores used as dependent variables, individuals scoring high on the ESS showed the following: higher levels of anger in, depression, and anxiety; lower levels of defensiveness, and high Brief Symptom Inventory values (Table 3). Men scored significantly lower than women on the Brief Symptom Inventory. Comparisons of groups with high and low ESS

scores during follow-up showed little difference from initial study phase findings. Consequently, only results of tests on initial phase data are presented. Slightly lower significance values at follow-up appeared to be a function of somewhat fewer subjects during follow-up.

## Discussion

Sleep disorders such as obstructive sleep apnea have been linked to elevations in BP and to hypertension<sup>5</sup> as well as to daytime sleepiness; however, this study indicates that subjective reports of daytime sleepiness are also associated with BP and hypertension. We found that high scores on the ESS were associated with a diagnosis of hypertension 5 years later. This conflicts with reports by Gus et al<sup>6</sup> that hypertension severity and degree of sleepiness on the ESS were not significantly correlated. However, the findings by Gus et al were not based on a prospective study. In addition, in contrast to our study, their population had the following characteristics: more extensive age range ( $\geq 18$  years), 89% diagnosed with hypertension, many subjects on medication, and no medical screening.

Cross-sectional data showed a relationship between high ESS scores and elevations in SBP and DBP during casual readings and during sleep. High scores were also associated with higher SBP level and DBP variability during waking hours. These findings were independent of age and BMI. Although casual BP was higher in men, an interaction between ESS scores and gender indicated that only men with high ESS scores were likely to exhibit elevations in casual DBP. Women had greater BP variability while awake during the day, and only those women with higher ESS scores showed higher SBP waking variability. It should be noted that we used multiple BP readings, many of which were intercorrelated. Our earlier findings indicated that all BP level measures (SBP and DBP casual, waking, and sleep) were part of a single



**FIG. 1.** Blood pressure (BP), given as the mean and SEM, in men and women with high and low scores on the Epworth Sleepiness Scale (ESS). \*Represents significant difference from that denoted by daggers ( $P < .05$ ). Numbers below columns represent  $n$  of each group. **Upper panel** represents casual diastolic BP; **lower panel** represents systolic BP variability during waking hours.



**Table 3.** Mean values ( $\pm$  SD) for psychosocial factors during initial phase of the study

Psychosocial Factor	Men (n = 65)	Women (n = 92)	High ESS (n = 34)	Low ESS (n = 123)
Anger in	13.9 $\pm$ 3.0	14.4 $\pm$ 3.5	15.3 $\pm$ 3.6†	13.1 $\pm$ 3.0
Anger out	13.5 $\pm$ 2.8	13.0 $\pm$ 3.1	13.7 $\pm$ 3.3	12.8 $\pm$ 3.0
Brief symptom inventory	12.6 $\pm$ 9.4†	17.9 $\pm$ 10.9	19.2 $\pm$ 13.1‡	11.3 $\pm$ 9.1
Hostility	14.4 $\pm$ 7.2	13.3 $\pm$ 7.5	15.4 $\pm$ 9.1	12.3 $\pm$ 6.8
Depression	0.96 $\pm$ 1.0	1.08 $\pm$ 1.1	1.36 $\pm$ 1.3†	0.68 $\pm$ 1.0
Defensiveness	20.0 $\pm$ 6.0	19.9 $\pm$ 5.7	18.8 $\pm$ 6.3*	21.2 $\pm$ 5.6
Anxiety	31.1 $\pm$ 6.6	31.8 $\pm$ 6.7	33.0 $\pm$ 7.2*	30.0 $\pm$ 6.5
Mini Mental State Exam	28.7 $\pm$ 1.1	28.4 $\pm$ 0.9	28.5 $\pm$ 1.1	28.6 $\pm$ 1.0

Values are derived from ANCOVA with Epworth Sleepiness Scale (ESS) and gender as factors and age as a covariate. Significance values are for men versus women and high versus low ESS groups.

\*  $P < .05$ ; †  $P < .01$ ; ‡  $P < .001$ .

factor. However, waking variability and sleep variability were unrelated to each other or to other BP measures, and were each found to be separate factors.<sup>23</sup>

In addition to being associated with increased BP, elevated ESS scores were related to higher anger in, depression, and anxiety, as well as to lower defensiveness. Prior studies have reported an association between EDS and depression.<sup>1,24</sup> In addition to depression, Olson et al<sup>7</sup> reported that, as in our findings, the ESS was correlated with psychological symptom intensity. They speculated that depressed individuals and those who somatize complaints may also overestimate their sleepiness. The relationship between psychosocial factors and the ESS was not due to the intervening effects of BP. When we repeated ANCOVA using BP measures as covariates, the findings did not change.

Other investigators have found that the information obtained by the ESS is unique.<sup>25</sup> According to Johns,<sup>12</sup> the ESS is an estimate of average sleep “propensity” (that is, the probability of falling asleep at a particular time) rather than a measure of subjective feeling of sleepiness. We did not find the ESS to be related to age, BMI, alcohol intake, caffeine use, exercise, education, activity, lipids, glucose levels, subjective sleep variables, or oximetry measures. This is consistent with other studies, although the ESS has been found to be associated with frequent awakenings, loud snoring, and limited physical activity.<sup>1</sup> Although the ESS has been compared to other measures of sleep such as the Multiple Sleep Latency Test and the apnea/hypopnea index, correlations were not very high.<sup>7,12,25</sup> The relationship between ESS and psychosocial variables suggests that, in addition to a propensity for sleep, this measure may include psychological factors as well.

Among the possibilities given to explain the relationship between EDS and cardiovascular endpoints, Punjabi and Haponik<sup>26</sup> proposed the following: 1) an underlying sleep disorder; 2) a chronic medical disorder; or 3) an undefined pathway influenced by sleep deprivation, leading to heightened sympathetic drive and elevations in catecholamines, or to alterations in the neuroendocrine axis resulting in increases in cortisol. The first two possi-

bilities appear unlikely because oximeter readings from our subjects during the follow-up showed little evidence of sleep apnea, and medical examinations found these individuals to be healthy. With regard to the third possibility, although subjects with higher ESS scores did not exhibit greater night-time activity levels, more night-time awakenings, or longer periods of being awake during the night than did subjects with lower ESS scores, our sleep questionnaires referred to 2 nights of ambulatory recordings and not to general sleep habits. Also, sleep deprivation is relative to a person’s needs. Consequently, increased catecholamines or cortisol associated with sleep deprivation could provide a link between daytime sleepiness and increased BP.<sup>26</sup>

Interpretation of these findings should be made in the context of the specific population sampled. This was a relatively homogeneous group of healthy, highly educated individuals who were primarily nonsmokers and exercised frequently. All medical and psychological tests were within the normal range. No subjects had ever been diagnosed with a major health disorder, or had been diagnosed previously as hypertensive or having any sleep problems. Also, subjects scored close to the upper limits on the MMSE (score of  $\geq 26$ ), making it unlikely that high and low ESS groups would be differentiated.

It has been suggested that high ESS scores, without other information, are not necessarily indicative of a sleep disorder.<sup>12</sup> However, even in our healthy sample of subjects, those with higher ESS scores were more likely to have elevated BP, increased BP variability, and higher levels of anger in, depression, anxiety, increased intensity of psychological symptoms, and lower defensiveness. The concept of sleepiness as a “normal” part of aging certainly needs to be re-examined in the same way that the concept that sleep disruption as a normal part of aging has been re-evaluated.<sup>27</sup> The link between ESS and BP is an important finding and confirms prior reports that older individuals at increased risk for cardiovascular disorders can be identified by daytime sleepiness.<sup>2,3</sup> Furthermore, it underscores the necessity of determining whether the diagnosis and treatment of daytime sleepiness can aid in

reduction in BP and ultimately in decreased morbidity and mortality from cardiovascular disorders.

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